

Morphodynamic Feedbacks During Vegetation Colonization of Tideflats

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LONG-TERM GOALS

The long-term goal of this effort is to understand interactions and feedbacks between biotic and physical process in tideflat morphodynamics. Investigated biotic processes consist primarily of vegetation colonization of tideflats. Physical process include those related to hydrodynamics: flow, sediment transport, salinity regime, inundation period, wave/storm disturbance, flood disturbance.

OBJECTIVES

1. To describe early vegetation colonization process in sandy tideflats. This would include determining rates of change, vegetation species involved, successional patterns (if any), and changes in tideflat biophysical structure, e.g., canopy density and height (in anticipation of these parameters being used in hydrodynamic models).
2. To discern physical controls on the colonization process, e.g., topography, sediment quality, hydrodynamics, salinity regime.
3. To discern physical consequences of vegetation colonization, e.g., direct and indirect topographic responses, including possible channel formation or stabilization and changes in sediment quality.

APPROACH

The project approach includes GIS change analysis, RTK-GPS topographic surveys, a space-for-time substitution sampling design, quantification of vegetation and sediment quality, and development of conceptual and statistical models of colonization processes and consequences. GIS change analysis was used to identify patterns and rates of channel change and vegetation development. It included analysis of orthophotos from 2004, 2006, 2007, and 2009 with pixel resolution ranging from 15cm to 45cm. RTK-GPS topographic surveys identified the topographic circumstances that characterize the locations of various species of marsh vegetation, on new islands as well as reference marshes. Additionally, these surveys (at 0.25 to 1.0 m grid resolution depending on island size, and 2 cm horizontal, 3 cm vertical accuracy) identified topographic features and patterns associated with colonizing vegetation, e.g., U-shaped scour channels and island lee deposition tails (Figs. 1, 2).

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Figure 1. *U-shaped scour and deposition tail (smooth ridge to right of island) associated with new *Schoenoplectus americanus* island at low tide. Survey rod in foreground = 1.5 m. Dominant flow is from left to right. To the right is a TIN model of the same island, where cold – warm colors represent low – high elevations. The U-shaped scour pool is in blue; the vegetated island is in red; the depositional sediment tail is in orange.*



Figure 2. *Left frames: Two perspectives on the same U-shaped scour associated with a relatively large (31m long), multi-species island at low tide that is visible in aerial photos as old as 1972 and 1980. The upper right frame shows the disposition of river distributaries relative to the island in 2004. The island likely received significant ebb tide and high river discharge flow during high water tide stages, and these would account for the scour pond. The lower right frame shows a TIN model of the same island (2007 background photo), where cold – warm colors represent low – high elevations. The U-shaped scour pool is in blue; the vegetated island is in red; the depositional sediment tail is in orange.*

WORK COMPLETED

The project focused on small, incipient, marsh islands in tidal flats near the outlet of the principal distributary of the North Fork Skagit River (Fig. 3). Most of these islands are located in a region where the course of the distributary outlet has recently been very dynamic. RTK-GPS surveys have been made of 8 incipient marsh islands ranging in size from 0.64m^2 to 1180m^2 and has included simultaneous notation of vegetation species associated with each survey point. Vegetation surveys have also included characterization of mature tidal marsh as a reference to colonizing vegetation. Work during the current project year has consisted primarily of data analysis and manuscript writing (e.g., publication of Hood 2010).



Figure 3. General location of the study area (yellow rectangle), relative to the principal distributary of the North Fork Skagit River. Photo is from the spring, 2009.

RESULTS

Historical aerial photos from 1956 to 2006 (eight photos: 1956, 1965, 1972, 1980, 1990, 2000, 2004, 2006), without exception, show the study area distributary continuing straight on its course from the tidal marsh across the tidal flats. However, in 2007 the channel suddenly changed course at a nearly right angle to the west (Fig. 4). Observing eight photos without a significant change in channel course is probable ($P > 0.10$) only if the straight course occurs at least three times more frequently than the westward-bending course. The likely cause of the sudden shift in the course of this distributary appears to be a large windstorm on 15-16 November 2006 which sustained winds from the south-south east (148-153 degrees) of 80 to 100 km/h for 10 hours, with gusts up to 115 km/h. River flow during this storm was 2-3 times mean annual flow.

Most of the incipient marsh islands investigated in this study are located in this area of recent channel dynamics (Figs. 5). Island topography has varied with the shifting course of the study area distributary (Fig. 6). The island tails, on the downstream side of the island, are formed by accumulations of flow-borne sediment deposited in the lee of the islands. Thus, these tails are indicators of recent dominant flow directions. The islands in this dynamic area have acted like weather vanes; the depositional sediment tails have shifted direction with shifting channel courses and flow direction. Fieldwork in 2010 indicated significant changes in channel course are continuing and these may also be related to wind forcing. The cut bank of the distributary bend had an interesting break where the east half of the bank has moved north, encroaching on the older channel course, while the west half of the bank has moved south and west. Either the river is dropping sediment in the east half, sediment is being pushed from the bay flats into the east half by waves, or both are occurring. Additionally, three of the small study island in this area were eroded away by channel migration. Channel migration has also changed the angle at which current flow is impinging on two other study islands and this is affecting island topography and vegetation colonization.

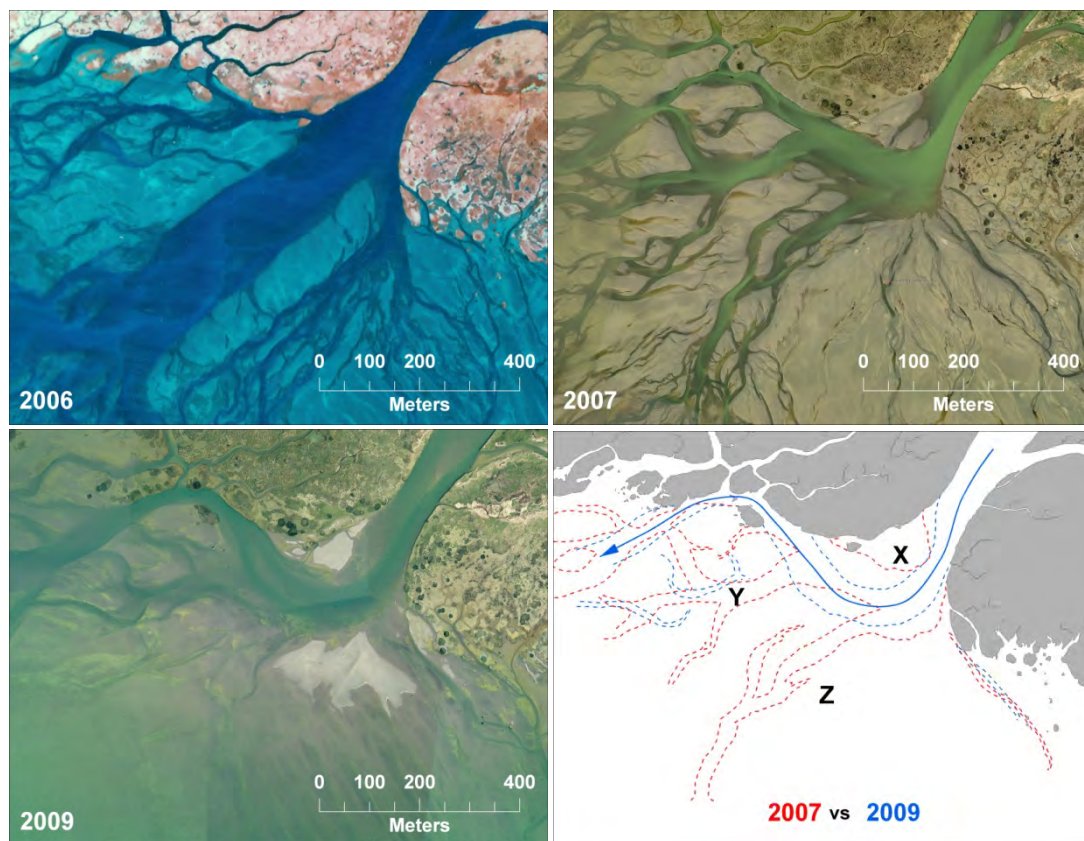


Figure 4. Comparison of the course of the study area distributary across the tidal flats. North is to the top of each frame. The main course of the distributary flows straight toward the SW in 2006, but bends to the west in 2007. The lower right frame illustrates growth in a point bar (X) from 2007 to 2009, which caused the channel bend curvature to tighten and the channel bend to migrate slightly. Digitized channels are limited to larger tide flat channels. Secondary tide flat channels diminish in some areas (Y) and disappear entirely where the main course of the distributary was located in 2006 and earlier years (Z). Note high elevation of dry sandy areas in the 2009 photo, as indicated light gray color in the point bar and opposite bank, indicating significant accumulation of sediment in these areas.

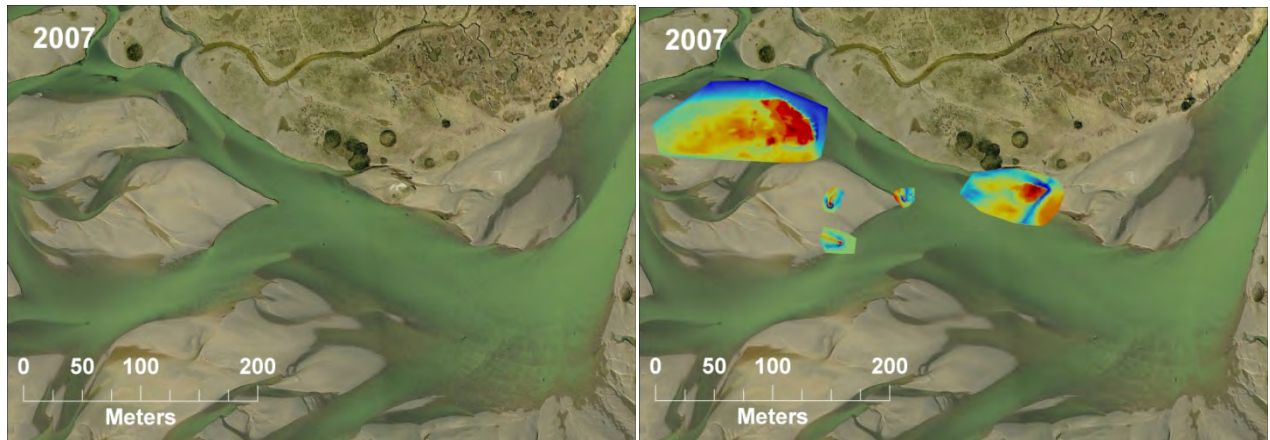


Figure 5. Five of eight study islands are located in the area of river distributary dynamism. TIN models of island topography (right frame); cold – warm colors represent low – high elevations. The second island from the right is located at the apex of a sandbar (compare with left frame), suggesting the resistance provided by this vegetated point facilitated a split in channel flow.

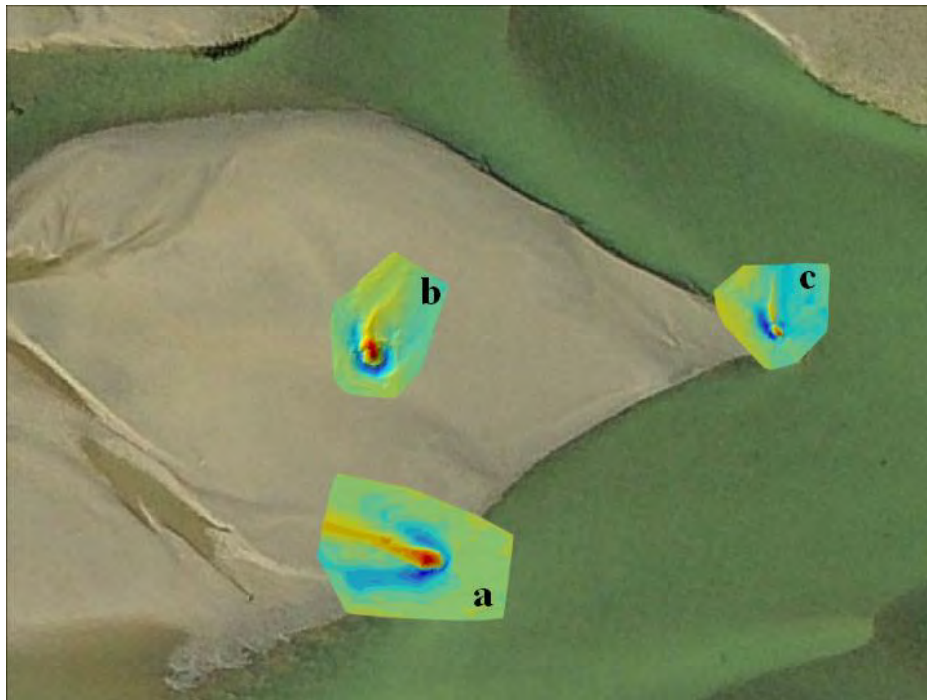


Figure 6. Three weather-vane islands – close-up of the central portion of Figure 3. The background photo is 2007. Island “a” was surveyed in 2008; the direction of its depositional tail and the location of its scour pool reflect a transition in flow direction from 2007 to 2008. Island “b” was not surveyed in 2008, but its less prominent tail and scour pool were situated similarly to those for island “a”. In 2008, islands “a” and “b” were on a sand flat at low tide with the main distributary channel to their right. Island “c” was in the center of the channel and was a navigation hazard. Islands “b” and “c” were surveyed in 2009 when the distributary had shifted so that islands “a” and “b” were in the channel at low tide and island “c” was on a point bar. The tail for island “a” disappeared by 2009, apparently eroded by flow normal to the tail. All three islands disappeared entirely in 2010, eroded by the shifting course of the river distributary.

The depositional sediment tails on the downstream side of the islands are being colonized by low density marsh vegetation. The most dynamic example of this is seen in the largest island surveyed, where significant vegetation expansion occurred from 2009 to 2010 on the sediment tail of the island (Fig. 7). *Schoenoplectus americanus*, typical of lower elevations, was the principal colonizing species. At higher elevations the marsh island vegetation transitioned from *Carex lyngbyei* to *Deschampsia caespitosa*, suggesting an increase in island elevation through sedimentation, although RTK-GPS point samples have exactly the same mean elevation (2.02 m, NAVD88) in both years (n = 45 and 32 in 2009 and 2010, respectively, in the relevant portion of the island head).

Historical traces of similar island colonization patterns can be inferred from allometric analysis of island form. Regression of sediment tail surface area on vegetated island surface area produces a strong scaling relationship (Fig. 8). Interestingly, a similar scaling pattern occurs within a single island (as indicated by identical power function exponents), where areas associated with the presence of different vegetation species and island-scale elevation bins fit the same allometric scaling patterns found among islands and their sediment tails. For example, in one small island, the highest point is occupied by clumps of *Deschampsia caespitosa*, followed by a lower “tail” of *Juncus balticus*; the “island” of *Deschampsia* and *Juncus* is in turn followed by a “tail” of *Schoenoplectus americanus*. Scaling of these successive pairs of vegetation patches and tails suggests sequential phases of vegetation colonization of the island as it grows in size and elevation, analogous to what is being observed on the much larger island depicted in figure 7.

Vegetation generally grows at lower elevations on the incipient marsh islands than in the mainland marsh (Fig. 9). The exception is the second largest island surveyed (Medium Island). On this island *Carex lyngbyei* and *Schoenoplectus americanus* grow at similar elevations as in the mainland marsh; *Juncus balticus* at only slightly lower elevation as in the mainland marsh. This exceptional behavior may be due to the surprisingly old age of Medium Island. It is clearly present in photos dating to 1972 but not 1965, making it approximately 43 ± 4 years old. In contrast, the largest island surveyed (Big Island) is visible in the 1998 air photo but not in the 1980 photo, making it approximately 22 ± 9 years old. Another factor that may affect the elevation at which island vegetation is observed to grow may be proximity to the distributary outlet. Medium island and island East 3 are both at the outlet of the largest North Fork distributary; East 3 island is located in an area where abundant new sand deposition has been observed over the last two years, with pre-established vegetation probably growing through newly deposited sand. Vegetation distributions are generally characterized in mature marshes, but newly colonized islands of *Carex lyngbyei* and *Juncus balticus*, in particular, appear to have significantly different elevation distributions from mature marsh. This may be due to differences in soil development or in scope for competition between species.

IMPACT/APPLICATIONS

Field surveys suggest a characteristic topography is associated with new or growing marsh islands in the tideflats that are also subject to significant tidal or riverine flow. These include U-shaped scour channels at the upstream end of the new island and deposition of fine sediments at the downstream tail of the island. Similar topographic patterns have been observed in braided fluvial systems except that islands in these systems are initiated by the deposition of large logs with root wads (Gurnell et al. 2005). Another significant difference, of course, is that flow in tidal systems is bi-directional. Nevertheless, the fluvial model may be a useful analog. Island growth appears to occur primarily through vegetation colonization of sediment tails. What stops island growth—the proximal cause is probably shifts in distributary channel courses, as indicated by the transient existence of the small

weather-vane islands. The weather-vane characteristic of the islands studied here (i.e., their responsiveness to changing channel courses and flow direction) may provide a useful field indicator of recent predominant flows. This may be useful in interpretation of remotely sensed data. Conversely, islands without depositional tails (not shown) appear to generally be distant from significant flow, which may also be a useful negative indicator.

RELATED PROJECTS

This project is related to other DRI projects <http://www.tidalflats.org/> located in the Skagit Delta, particularly those involving Jim Thomson and Chris Chickadel (Applied Physics Laboratory, University of Washington), Eric Grossman (USGS, Santa Cruz), Steve Henderson (Washington State University), and Brit Raubenhiemer and Steve Elgar (WHOI) all of whom are working in the North Fork area where much of this work has taken place.

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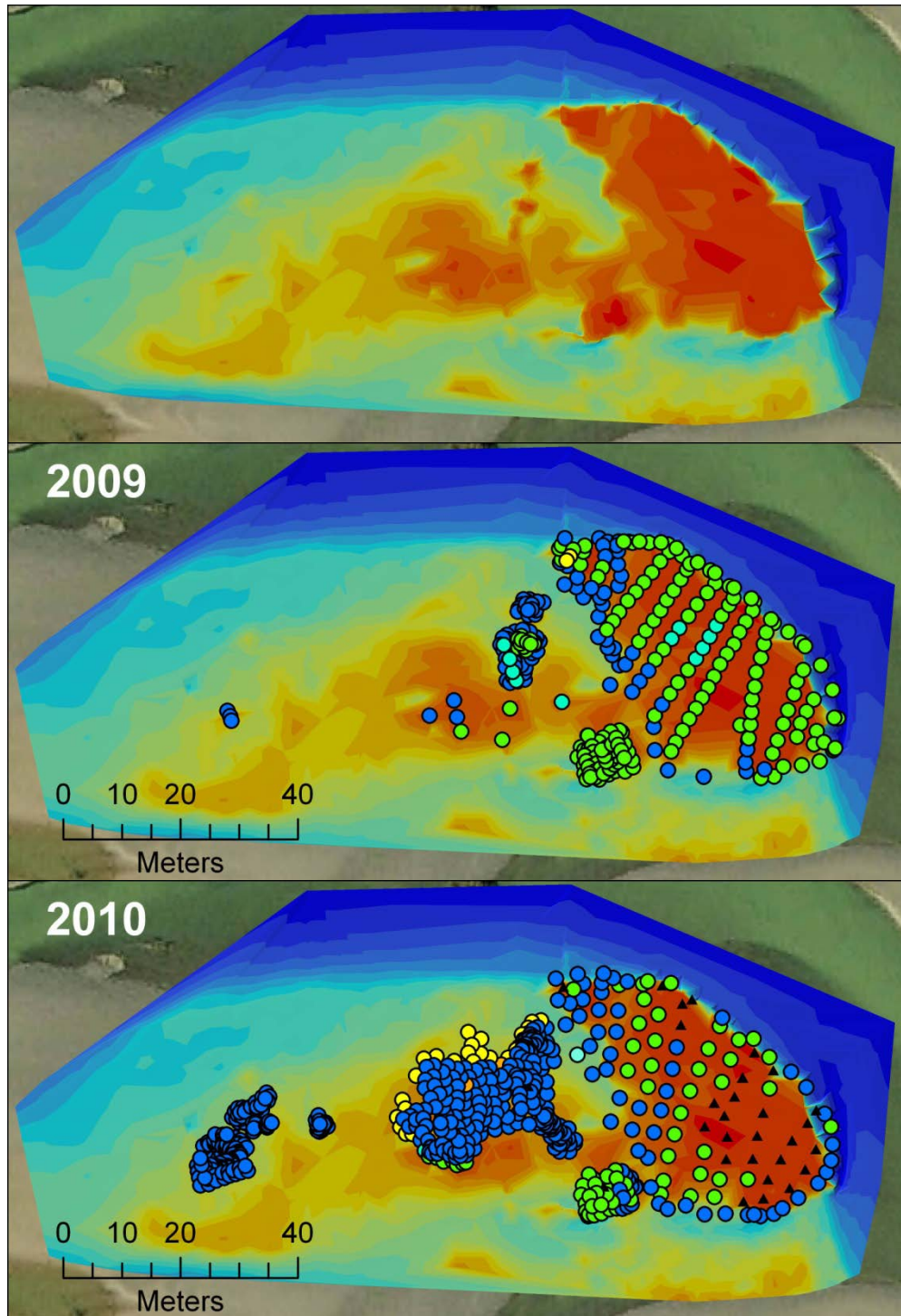


Figure 7. Island topography and vegetation. Top frames are for reference to unobstructed view of background image and TIN model. Bottom frame includes overlay of RTK-GPS points of vegetation from 2009 to 2010. Green points are *Carex lyngbyei*, blue are *Schoenoplectus americanus*, orange are *S. tabernaemontani*, light blue are *Eleocharis palustris*, yellow are *Juncus balticus*, black triangles are *Deschampsia caespitosa*. Colonizing vegetation is generally located on the relatively high-elevation, downstream, depositional sediment tail of the island.

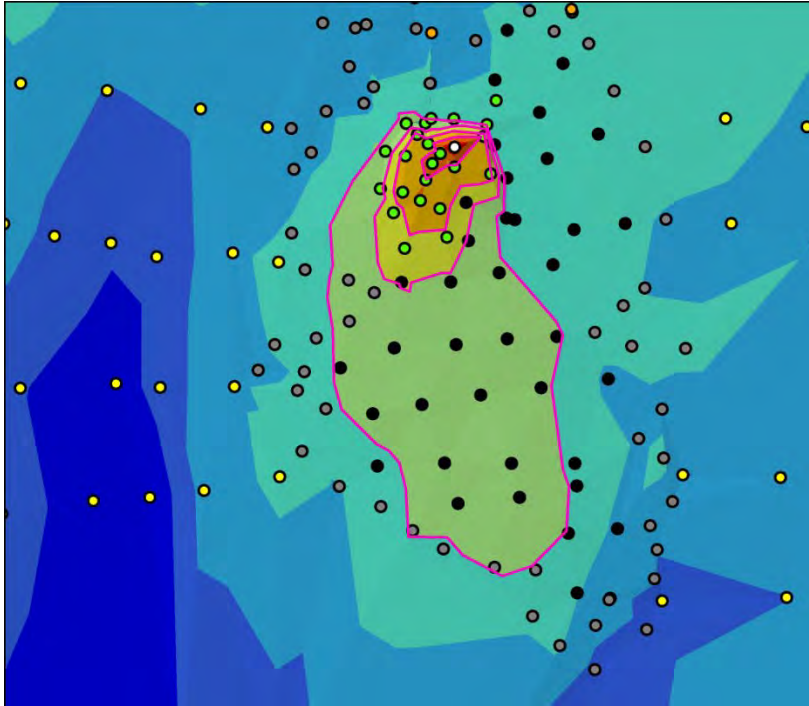
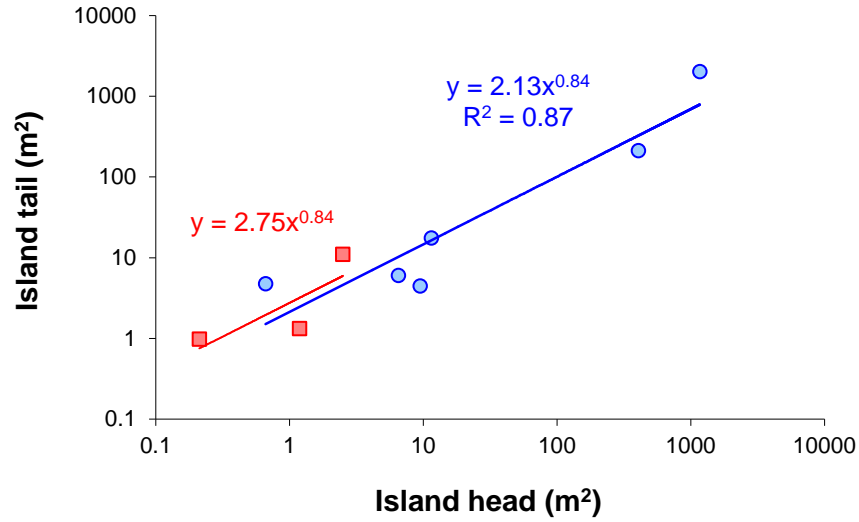


Figure 8. Allometric scaling of sediment tails with island heads for a variety of incipient marsh islands in the North Fork study area (blue circles, top frame). Similar scaling (red squares) is observed for a series of vegetation patches and “tails” in an individual island (bottom frame), where a patch of *Deschampsia caespitosa* (white circle) is followed by a tail of *Juncus balticus* (light green circles) which is followed by a tail of *Schoenoplectus americanus* (black circles). Gray circles represent low-density colonizing *S. americanus*; yellow circles represent bare sand. Background image is a tin representation of island topography, with vegetated isopleths used in the allometric analysis outlined in pink.

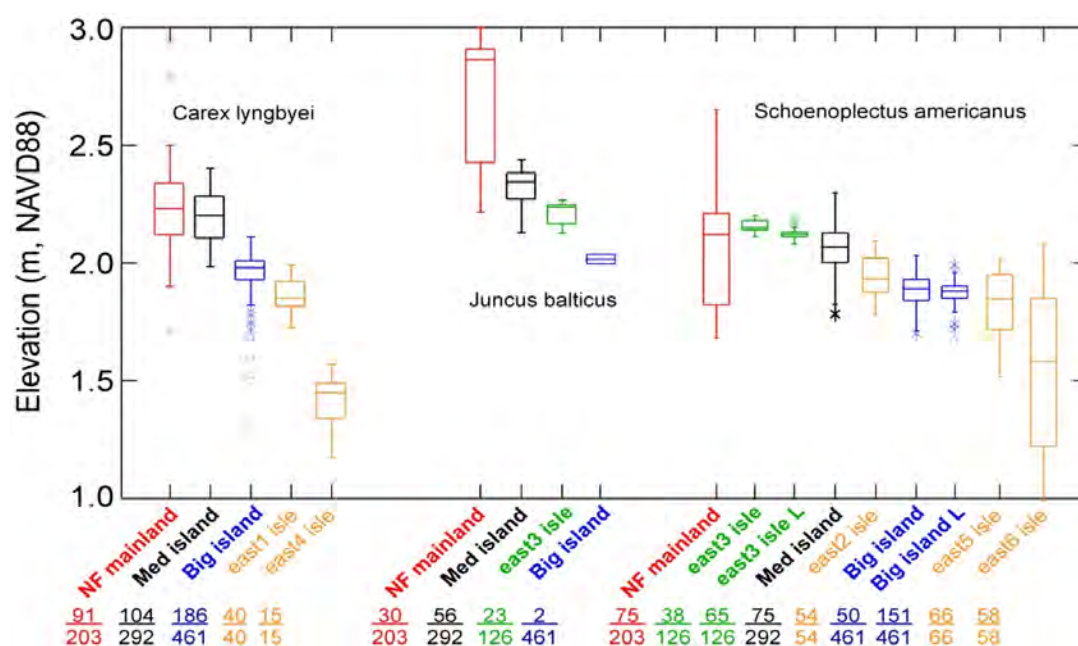


Figure 9. Box and whiskers plots of vegetation distributions in the North Fork mainland marshes and small marsh islands bayward of the mainland marsh (top frame). Fractions associated with island labels represent the sample size of the species depicted (numerator) and of all vegetation points sampled on the island (denominator). The locations of the islands are depicted in the lower frame.